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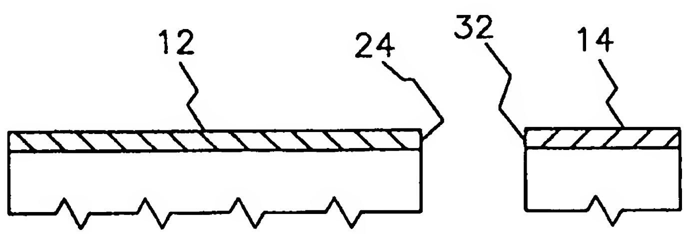
(54) Title: METHOD AND APPARATUS OF A STRONG METAL-CERAMIC BRAZE BOND

(57) Abstract



A microstimulator assembly (10) and method of making a microstimulator assembly (10) includes the use of a cylindrical or tubular ceramic case (12). A metal band (14) is bonded to one end of the ceramic case (12) and a conductive metal end cap is bonded to the opposite end, forming a housing assembly. The metal band (14) and the end cap are hermetically bonded to the ceramic case (12) by brazing. An electronic circuit assembly is inserted into the open end of the housing assembly until a first electrode contact thereon makes electrical contact with the end cap. Once the electronic circuit assembly is in place, a conductive spring is loaded into the open end of the tube until it makes electrical contact with the second electrode contact on the electronic circuit assembly. The conductive spring is compressed with a conductive sealing cap until the sealing cap engages the metal band (14). The sealing cap is then hermetically sealed to the metal band (14) by laser welding and remains in electrical contact with the second electrode contact of the electronic circuit assembly via the compressed, conductive spring. The end cap and sealing cap may also be coated with an electrically conductive coating. A welded or glued connection between all electrical circuits is also utilized in these instances to provide a redundant and secure electrical connection.

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METHOD AND APPARATUS OF A STRONG METAL-CERAMIC BRAZE BOND

This application claims the benefit of U. S. Provisional Application No. 60/125,852, filed March 24, 1999 and U. S. Provisional Application No. 60/126,514, filed March 26, 1999.

BACKGROUND OF THE INVENTION

Technical Field of the Invention

The present invention relates to connecting a ceramic and a metal with a metal alloy braze so as to form a strong connection between the ceramic and the metal.

Prior Art

Today, the most commonly used metals for human or animal body implantable packages are titanium, stainless steel and cobalt-chromium alloys. These metals are biocompatible and corrosion resistant. Normally, the package construction consists of parts that are welded together to insure hermeticity. However, where there is a need to inductively couple an alternating electromagnetic field to an internal pickup coil, the metal package becomes a hindrance. Specifically, eddy currents generated in the metal package due to the alternating electromagnetic field substantially reduce transmission of power. To solve that problem, receiving coils are often placed outside the metal package, increasing the size due to additional plastic insulation complexity and expense due to the needed hermetic feedthroughs, and additional safety electronics, (capacitors need to be in series with the coil leads) and reducing safety because the coil could make an undesirable electric contact with the body tissue and saline.

Electrical stimulation devices contain electrical components inside the package that are connected to stimulating leads by hermetic feedthroughs, which permit the flow of electrical currents through the package wall while maintaining hermeticity. Also, disadvantageously, each feedthrough is also possible leak path that can ruin the hermeticity of the package.

Glasses and ceramics represent viable materials for an implantable medical device package because they are transparent to alternating electromagnetic fields. Receiving coils can be placed inside a hermetic zone of a ceramic or glass package, creating an overall smaller and simpler implant device and reducing the possibility of coil failure due to saline leakage. Glasses and ceramics are inert and highly insoluble, which are favorable characteristics for long term implant materials.

Unfortunately, all known biocompatible glasses and ceramics are characterized by high sealing temperatures, which high temperatures may damage electronic components commonly included in electronic devices implanted in living bodies. Low-melting temperature glasses may not be used because they all have the property of being corroded by body fluids. Therefore, packages composed entirely of ceramic and/or glass have generally not been considered practical for implant applications. Also, because glasses and ceramics are inelastic, they are subject to fracture not only from mechanical shock but also from differential thermal expansion if even a moderate temperature gradient exists there across. Therefore, welding is not a practical method of sealing glass or ceramic materials. Instead, if a glass package is used, and it is desired not to have a differential thermal expansion, virtually the entire package and its contents must be raised to the high melting temperature of the glass or ceramic to effect a sealing of the glass or ceramic package. Such a sealing method is unsatisfactory because it would damage the electronic components contained in the device.

One type of hermetically sealed ceramic and metal package is shown in U.S. Patent No. 4,991,582, issued to Byers et al. and incorporated herein by reference. This patent shows a ceramic case and a metal band are hermetically sealed together using a braze, each being characterized by similar coefficients of linear thermal expansion. A brazeless ceramic-to-metal bond for use in implantable devices is shown in U.S. Patent No. 5,513,793, issued to Malmgren and incorporated therein by reference. The '793 patent describes a method and apparatus for forming a hermetically sealed bond between a ceramic case and a metal band. The ceramic case and the metal band are hermetically sealed together at elevated temperature and pressure. The ceramic and metal thus bonded are characterized by similar coefficients of linear thermal expansion. The electronic circuitry is then loaded inside the package, and welding a metal header plate to the metal band effects final package closure. This is quite safe from thermal gradients because the metal on both sides of

the weld can be heatsinked, and the weld performed by a high temperature but low caloric welding method such as a very narrow laser or electron beam. The metal can withstand the thermal stress which the glass and ceramic cannot.

Disadvantageously, glass is also transparent to light. Some components inside a glass package may be light sensitive and, if so, a light barrier must be provided, such as a film or mask covering the components to prevent undesired light from reaching the components.

In view of the above, it is evident that what is needed is an implantable package that is constructed from a material that is transparent to an alternating magnetic field and at the same time protects the electronic circuitry hermetically sealed therein, minimized the number of joints to be sealed, is not prone to cracking or leaking, and is cost effective to manufacture, and can be hermetically sealed without submitting the internal components to a potentially damaging high temperature.

SUMMARY OF THE INVENTION

The present invention advantageously addresses the need above and other needs by providing an apparatus and method for manufacturing a strong ceramic-metal bond.

The metals made from a biocompatible material that has the same coefficient of thermal expansion (CTE) as the ceramic material. The attachment of the metal band and end cap to the ceramic case may be a beveled joint or stepped butt joint or combination for self-jigging. The attachments are all hermetic seals. The preferred method of attachment is brazing the metals to the ceramic case using a metal or metal alloy braze. Such brazing, while performed at a high temperature, may be done without the electronic circuitry being present. The same attachments could be made with brazeless methods such as in the '793 patent mentioned above.

The metals used for the end cap and sealing cap must have the following properties, a) the coefficient of thermal expansion must match the ceramic, b) the surface chemistry must permit strong adhesion to the braze or ceramic, c) the exposed metal surface must not damage body tissue (biocompatible towards tissue), d) the exposed metal surface must not be damaged by crevice corrosion and by fluids (biocompatible relative to tissue and e) the seal must be able to withstand an amount

of electrical current, up to some maximum amount, flowing through the metal-saline interface without any electrolytic corrosion.

BRIEF DESCRIPTION OF THE DRAWINGS

The above and other aspects, features and advantages of the present invention will be more apparent from the following more particular description thereof, presented in conjunction with the following drawings wherein:

Figure 1 is a cross-sectional exploded view of part of an assembly including a ceramic cylindrical case or ceramic part, a metal band or a metal part;

Figure 2 is a cross-sectional view of part of the assembly showing the ceramic part or case and the metal band or part.

Figure 3a shows the cross-sectional view of a ceramic cylindrical housing and metal or metal alloy assembly, with a self-jigging bevel joint.

Figure 3b shows the cross-sectional view of a ceramic cylindrical housing and metal or metal alloy before assembly, with a self-jigging bevel joint and braze preform.

Figure 4a shows the cross-sectional view of a ceramic cylindrical housing and metal or metal alloy assembly, with a self-jigging step joint.

Figure 4b shows the cross-sectional view of a ceramic cylindrical housing and metal or metal alloy before assembly, with a self-jigging step joint.

DETAILED DESCRIPTION OF THE INVENTION

The following description of the presently contemplated best mode of practicing the invention is not to be taken in a limiting sense, but is made merely for the purpose of describing the general principles of the invention. The scope of the invention should be determined with reference to the claims.

Figures 1 and 2 show the unassembled structure and the assembled structure of a ceramic and a metal or metal alloy brazed assembly with a strong bond. Referring first to Figure 1, a cross-sectional exploded view is shown of the components used in the assembly 10. These components include a ceramic element 12 and a metal or metal alloy 14. In Figure 2, the ceramic 12 and the metal 14 are joined together with a hermetically sealed bond, such as a metal or metal alloy of nickel and titanium braze, shown as bonding site 18. The ceramic 12 and the metal 14 have similar dimensions out of the plane of the drawing and are shown with a butt attachment.

Figure 3a shows an optional bevel joint attachment of the metal or metal alloy cylindrical band 14 to the cylindrical ceramic case 12 that could be used for self-jigging in this or a similar type of geometry. The case and band could be square or rectangular or prismatic, but with the corresponding beveled surfaces. The acute angle (Figure 3a, 19) of the bevel can vary from 0.00001° to 90° (butt joint). The bevel joint of Figure 3a is particularly advantageous because as the angle (19) of the bevel changes, the length of the braze changes. As the acute angle (19) becomes smaller, the length of the joint becomes longer. This makes it possible to increase the braze distance while decreasing the wall thickness (figure 3a, 17). Consequently a hermetic seal can obtain with very thin walls. Increasing the bevel angle (19) decreases the hermetic seal length. Typical hermetic seal lengths range from 1 mil to 5 mils and longer. An exploded view of Figure 3a is shown in Figure 3b with the braze preform (15) visible.

The ceramic element or case 12 is preferably made from a biocompatible ceramic material, e.g., aluminum oxide, and most preferably from zirconium oxide with about 3% yttrium. The ceramic is tends to be somewhat translucent in its original form; it can be altered to not pass light. When the ceramic is coated or impregnated with a substance such as titanium, titanium ions are incorporated into the ceramic and the ceramic is made opaque. As modified it can protect the internal components that are sensitive to light.

The element or band 14 is made from a biocompatible metal, e .g. titanium, stainless steel, niobium, molybdenum, tantalum and cobalt-chromium alloys, and preferably from alloys of titanium-45 niobium (i.e., 55% Ti and 45% Nb) or any other metal or alloy that readily forms an instant oxide when heated, i.e., that readily oxidizes when heated in an oxygen-containing atmosphere. Note that both the zirconium oxide and the titanium-45 niobium have similar coefficients of thermal expansion (CTE) of between 8 and 9 $mm^3/^oC$. This minimizes the risk of cracking when the ceramic element or case 12 and metal or metal alloy element or band 14 are bonded together at high temperatures and then cooled.

The range of the titanium-niobium alloy is from 20% niobium-80% titanium to 60% niobium-40% titanium.

Once engaged, they are brazed together using a metal or metal alloy braze at bonding site 18 (as shown in Figure 2).

Figure 3a shows the assembled ceramic-metal/metal alloy assembly 10. Many well-known processes may be used to hermetically bond the metal/metal alloy structure 14 to the end of the ceramic structure 12 utilizing biocompatible sealing materials. Some of these methods are described in U.S. Patent Numbers 4,991,582 and 5,513,793, previously incorporated herein by reference.

In a preferred method of manufacturing the assembly 10, the brazing of the metal band 14 is done with a nickel-titanium (NiTi) braze, preferably 50%Ni-50%Ti. It is desirable for the CTE of the braze be similar to the metal and ceramic. The brazing operation may also be done in a production line operation to manufacture more than one assembly 10 at a time. Figure 4a shows the assembly with a self-jigging step joint attaching the metal band (14). Figure 4b shows the ceramic element or cylinder (12) and the metal band (14) before assembly with the NiTi braze.

The range of the braze composition is from 100% nickel to 20% nickel and 80% titanium.

While the invention herein disclosed has been described by means of specific embodiments and applications thereof, numerous modifications and variations could be made thereto by those skilled in the art without departing from the scope of the invention set forth in the claims.

CLAIMS

What is claimed:

1. A strong braze bond comprising a braze metal or braze metal alloy, which is heated during the bonding process and which is applied to the interface of a metal or metal alloy and a ceramic, and said interface is placed under pressure so as to press the bonding surfaces together.

2. The strong braze bond of claim 1 formed from a conductive material having a coefficient of thermal expansion substantially the same as that of the ceramic and as that of the metal.

3. The strong braze bond of claim 2 wherein the metal alloy braze is selected from the group consisting of the nickel-titanium alloys with nickel-titanium percentages in the range from nickel (100%)-titanium (0%) through nickel (20%)-titanium (80%).

4. The strong braze bond of claim 3 wherein the brazing temperature is about 1020 °C and the brazing pressure is about 200 lbs/sq. in.

5. The strong braze bond of claim 4 wherein the metal or metal alloy is hermetically bonded to the ceramic by the braze.

6. The strong braze bond of claim 3 wherein the metal alloy braze is made as a pre-form that is self-aligning between the metal and ceramic parts.

7. The strong braze bond of claim 3 wherein one end of the ceramic and one end of the metal are beveled to define a self-jigging junction between the ceramic case and the metal band during bonding forming a beveled joint.

8. The strong braze bond of claim 7 further comprising an acute bevel angle in the range 0.0001° through 90° (butt joint).

9. The strong braze bond of claim 7 further comprising an hermetic seal wherein the joint length is 1 micron or longer.

10. The strong braze bond of claim 2 wherein the one end of the ceramic and one end of the metal are stepped to define a self-jigging junction between the ceramic case and the metal band during bonding forming a stepped joint.

11. The strong braze bond of claim 1 wherein the ceramic comprises an inert ceramic selected from the group consisting of aluminum oxide and zirconium oxide, and the metal (to be joined to the ceramic) is selected from the group consisting of niobium, molybdenum, tantalum, titanium, platinum, and iridium.

12. The strong braze bond of claim 3 wherein the braze joints are dipped in nitric acid so as to get rid of the nickel in the exposed surface areas.

13. The strong braze bond of claim 7 wherein the ceramic is made from zirconium oxide with 3% yttrium and the metal (to be joined to the ceramic) is made from a titanium-niobium alloy.

14. The strong braze bond of claim 7 wherein the metal (to be joined to the ceramic) is made from a titanium –niobium alloy selected from the group consisting of the titanium-niobium alloys with titanium-niobium percentages in the range from titanium (80%)-niobium (20%) through titanium (80%)-niobium (60%).

15. An opaque ceramic comprising a ceramic coated with titanium atoms.

16. The opaque ceramic of claim 15 further comprising the ceramic selected from the group consisting of aluminum oxide and zirconium oxide.

17. An opaque ceramic comprising a ceramic impregnated with titanium atoms.

18. The opaque ceramic of claim 17 further comprising the ceramic

selected from the group consisting of aluminum oxide and zirconium oxide

19. A method for making a strong braze bond comprising the steps of heating a braze metal or braze metal alloy during the bonding process, and applying the braze to the interface of a metal or metal alloy and a ceramic.

20. The method of claim 19 comprising the further step of selecting a braze which is a conductive material having a coefficient of thermal expansion substantially the same as that of the ceramic and as that of the metal.

21. The method of claim 20 comprising the further step of selecting the braze to be a metal alloy braze of nickel and titanium from the group consisting of the nickel-titanium alloys with nickel-titanium percentages in the range from nickel (100%)-titanium (0%) through nickel (20%)-titanium (80%).

22. The method of claim 21 further comprising the steps of utilizing a brazing temperature of about1020 °C; and utilizing a brazing pressure of about 200 lbs/sq. in.

23. The method of claim 21 further comprising the step of hermetically bonding the metal or metal alloy to the ceramic by the braze.

24. The method of claim 23 comprising the further step of pre-forming the braze as a pre-form that is self-aligning between the metal and ceramic parts.

25. The method of claim 21 further comprising the steps of beveling one end of the metal and conversely beveling one end of the ceramic so that they are can mate together and so define a self-jigging junction between the ceramic case and the metal band during bonding forming a beveled joint.

26. The method of claim 25 further comprising the step of selecting an acute bevel angle in the range 0.0001 ° through 90 ° (butt joint).

27. The method of claim 25 further comprising the step of forming an hermetic seal wherein the joint length is 1 micron or longer.

28. The method of claim 24 further comprising the steps of forming a step at one end of the metal and conversely forming a step at one end of the ceramic so that they are can mate together and so define a self-jigging junction between the ceramic case and the metal band during bonding forming a stepped joint.

29. The method of claim 19 further comprising the steps of selecting the ceramic from the group consisting of aluminum oxide and zirconium oxide, and selecting the metal (to be joined to the ceramic) from the group consisting of niobium, molybdenum, tantalum, titanium, platinum, and iridium.

30. The method of claim 19 further comprising the step of dipping the braze joints in nitric acid so as to get rid of the nickel in the exposed surface areas.

31. The method of claim 29 further comprising the steps of making the ceramic from zirconium oxide with 3% yttrium and the making the metal/metal alloy (to be joined to the ceramic) from a titanium-niobium alloy.

32. The method of claim 31 further comprising the step of making the metal/metal alloy (to be joined to the ceramic) from a titanium-niobium alloy selected from the group consisting of the titanium-niobium alloys with titanium-niobium percentages in the range from titanium (80%)-niobium (20%) through titanium (80%)-niobium (60%).

33. A method of making ceramics opaque comprising the step of coating a ceramic with titanium atoms.

34. The method of claim 33 further comprising the step of selecting the ceramic from the group consisting of aluminum oxide and zirconium oxide.

35. A method of making ceramics opaque comprising the step of impregnating a ceramic with titanium atoms.

36. The method of claim 35 further comprising the step of selecting the ceramic from the group consisting of aluminum oxide and zirconium oxide.

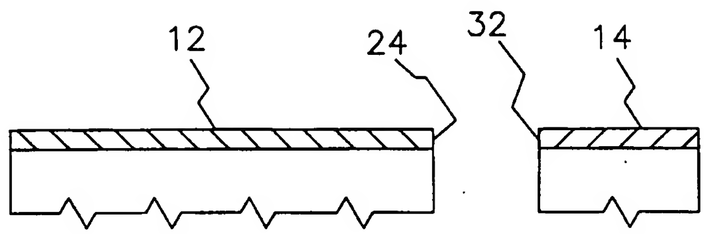

FIGURE 1

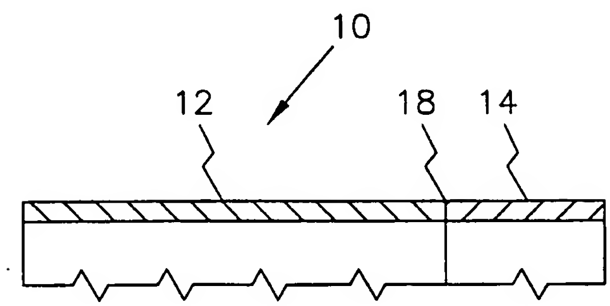

FIGURE 2

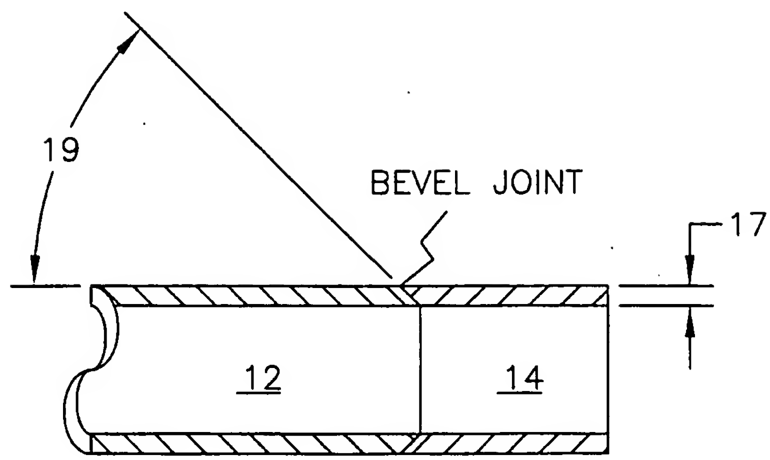

FIGURE 3a

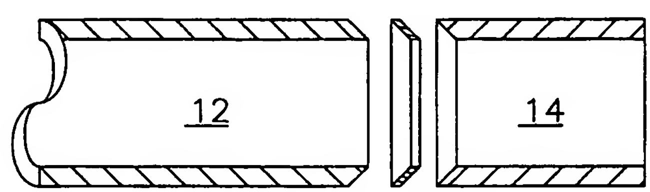

FIGURE 3b

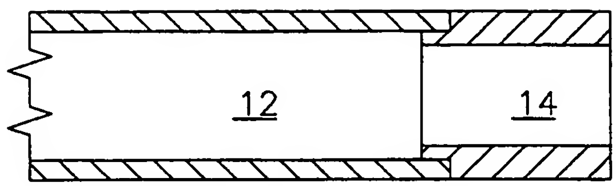

FIGURE 4a

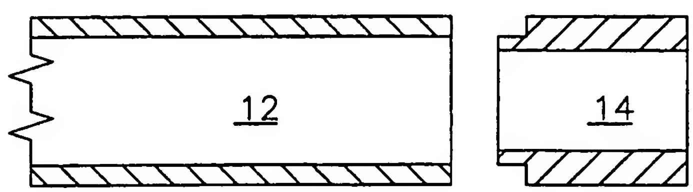

FIGURE 4b

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US00/07601

A. CLASSIFICATION OF SUBJECT MATTER

IPC(7) :Please See Extra Sheet.
US CL :Please See Extra Sheet.
According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

U.S. : 428/621, 627, 632, 633
228/122.1, 124.6

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 4,991,582 A (BYERS ET AL.) 12 FEBRUARY. 1991, SEE WHOLE DOCUMENT	1-5,11, 15-23, 33-36
Y	US 5,513,793 A (MALMGREN) 7 MAY 1996, SEE WHOLE DOCUMENT	1-36
Y	US 5,738,270 A (MALMGREN) 14 APRIL 1998, SEE WHOLE DOCUMENT	1-36
X, E	US 6,011,993 A (TZIVISKOS ET AL.) 4 JANUARY 2000, SEE WHOLE DOCUMENT	1-5, 9, 11, 13-23, 29, 31-36

☐ Further documents are listed in the continuation of Box C. ☐ See patent family annex.

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Date of the actual completion of the international search 02 JUNE 2000	Date of mailing of the international search report 31 JUL 2000
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INTERNATIONAL SEARCH REPORT

International application No.
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A. CLASSIFICATION OF SUBJECT MATTER:
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A. CLASSIFICATION OF SUBJECT MATTER:
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